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digits 1 through 4 are assigned to four rotations about a midpoint of the at least one of the regular pentagon and the dihedral group, and digits 5 through 9 are assigned to five reflections about five axes of symmetry of the at least one of the regular pentagon and the dihedral group.

35. The method of claim 18, wherein the binary number is a binary code specific to an individual.

REMARKS

This Preliminary Amendment cancels without prejudice original claims 1 to 17 in the underlying PCT Application No. PCT/EP00/02481, and adds without prejudice new claims 18 to 35. The new claims conform the claims to U.S. Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to U.S. Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked Up Version Of The Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. In the Marked Up Version, double-underlining indicates added text and bracketing indicates deleted text. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/EP00/02481 includes an International Search Report, dated August 30, 2000. The Search Report includes a list of documents that were uncovered in the underlying PCT Application. A copy of the Search Report accompanies this Preliminary Amendment.

The underlying PCT Application No. PCT/EP00/02481 also includes an International Preliminary Examination Report, dated February 26, 2001, and an annex associated with the International Preliminary Examination Report. An English translation of the International Preliminary Examination Report and of the annex accompanies this Preliminary Amendment.

Applicants assert that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

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METHOD FOR GENERATING IDENTIFICATION NUMBERS

FIELD OF THE INVENTION

The present invention [is directed] relates to a method for generating a personal identification number (PIN), made up of a number of N decimal digits, to be used for money cards and other devices requiring security, from a binary number having L digits, in[] particular from a binary code specific to an individual.

BACKGROUND INFORMATION

When using automatic cash dispensers, such as ATM machines or similar devices where a plastic card is utilized, the user must often use a four-digit number (PIN) known only to himself in order to receive authorization. There are, by far, however, not as many different PINs as there are users, which is why each PIN exists many times over.[]

The PINs may only contain decimal digits, to enable them to be entered using numerical keypads. In addition, they are not supposed to begin with a zero. This means that, given four digit positions, the result is a range of 9000 different PINs. The theoretically lowest probability of correctly guessing a PIN is, thus, 1/9000.

[The object] SUMMARY OF THE INVENTION

An exemplary method and/or exemplary embodiment of the present invention is directed to [provide] providing a method which will keep the probability of a PIN being correctly guessed as low as possible.[]

[The realization underlying the present invention is that w]When the PINs are generated such that they are randomly

MARKED UP VERSION OF THE SUBSTITUTE SPECIFICATION

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uniformly distributed over the available number domain, the probability of a PIN being correctly ascertained may then become[s] minimal. [This is elucidated on the basis of the following example.]

5

With the aid of an encryption algorithm, a secret key may be used to produce a binary code from personal data pertaining to the user. Using the DES (data encryption standard) or triple DES algorithm provided, for example, for generating PINs for
10 money cards, a 64-digit binary code is generated from the data pertaining to one customer, with the assistance of a bank-specific key. From a 16-digit segment of this binary code, the PIN can be generated in the following manner[, for].

15 For example[:

Four], four parts for each of the four digits of this binary number are combined into four decimal numbers. These four decimal numbers are divided by 10 (modulo function) to yield
20 the four digits of the PIN as a remainder of a division. If the first digit is a zero, it is replaced by a one. To a large degree, however, the resultant PINs are unevenly distributed over the available number domain of 1 to 9000. If it begins with a 1, a PIN generated in this manner has a probability of
25 being correctly guessed of even greater than 1/150.

If, on the other hand, [one distributes the PINs] the PINs are distributed uniformly over the number domain, then the rate of occurrence of each PIN is constantly 1/9000, and the
30 probability of it being correctly guessed is, therefore, also minimal.

[A first] Another exemplary embodiment and/or exemplary method of the present invention provides for the first n1 digits of
35 the binary number (B) to be converted in [generally known fashion] an available manner into a decimal number d1, the

predefinable natural number n_1 being selected so as to yield a natural number z_1 such that the quotient $2^{n_1}/(z_1*9)$ is close to 1; and for the first decimal digit of the PIN to receive the value d_1 modulo 9; for $N-1$ further groups of further n_2 digits of the binary number (B) to be converted each time in [generally known fashion]an available manner into $N-1$ decimal numbers d_2 through d_N , the predefinable number n_2 being selected so as to yield a natural number z_2 such that the quotient $2^{n_2}/(z_2*10)$ is close to 1, [the intention being] to satisfy the condition: $0 \leq 2^{n_2} \text{ modulo } 10 < 3$; and for the decimal digits 2 through N of the PIN to receive the values d_i modulo 10, $i=2$ through N .

To generate the first digit of the PIN, n_1 is selected so that 2^{n_1} is close to a multiple of 9. The $n-1$ digit part to the front of the binary number is interpreted as a decimal number. The integer remainder is calculated by dividing by 9. This remainder forms the first digit of the PIN. To generate digit 2 and the following digits of the PIN, n_2 bits are split off each time. The number n_2 is selected such that 2^n is close to a multiple of 10. The resulting number is interpreted as a decimal number. The integer remainder is calculated by dividing by 10. This remainder forms the respective digit of the PIN. It is true that no absolute uniform distribution is derived hereby. However, the greater n_2 is, the more uniformly the PIN numbers are distributed.

For example, selecting $n_2=13$ results in a number domain of from 1 to $2^{13}=8192$. The digits 0, 1, 2 and 3 occur in the generated PINs with a probability of $820/8192$, and the remaining digits with a probability of $819/8192$. [In particular, the]The exemplary embodiments and/or exemplary methods of the present invention may avoid[s] having the 1 occur all too often in the first digit position of the PIN.

A further exemplary embodiment and/or exemplary method of the present invention [provides] is directed to providing for n_1 and $n_2 \leq 16$ to be predefined.

5 [Yet another] A further exemplary embodiment and/or exemplary method of the present invention [provides] is directed to providing for $N=4$ to be selected.

10 [Furthermore, it may be provided] A further exemplary embodiment and/or exemplary method of the present invention is directed to providing for the binary number (B) to have the length $L=16$, for $N=4$ to be predefined, and for $n_1=n_2=4$ to be predefined.

15 [Yet another] A further exemplary embodiment and/or exemplary method of the present invention [provides] is directed to providing for the binary number (B) to have the length $L=3 \cdot n_3$, for n_3 groups of three digits of the binary number (B) to be converted in [generally known fashion] an available manner into n_3 decimal digits to generate the digits of the PIN, n_3 being a natural number. In this variant, altogether 12 bits of the customer-specific binary code are used to generate the PIN. In
20 each case, three bits of this binary number are interpreted as decimal digits between 1 and 8. The PINs produced in this manner are absolutely uniformly distributed.

25 Another [possibility] exemplary embodiment and/or exemplary method for generating absolutely uniformly distributed PINs within the particular number domain provides for the binary number to be completely converted into a decimal number, in order to generate the PIN in [generally known fashion] an available manner, and, if necessary, to add a correction value to the resultant decimal number such that the first digit of
30 the decimal number becomes unequal to zero, the digits of the result forming the digits of the PIN.

To this end, it may be provided for the binary number to have a length L of 13, for the generated decimal number to have four digits, and for a preset value greater than 999 and smaller than 1807 to be added to the decimal number; for the
5 binary number to have a length L of 16, for the generated decimal number to have five digit positions, and for a preset value greater than 9999 and smaller than 34465 to be added to the decimal number.

10 Furthermore, it may be provided in the first case (L=13) for the set of numbers 0 through 8191 to be allocated to n_5 subsets M_1, \dots, M_{n_5} , and for a preset value d_i to be added to the generated decimal number if it is an element of the set M_i , it holding that $999 < d_1 < d_2 < \dots < d_{n_5} < 1809$, and n_5 being a
15 natural number.

Furthermore, it may be provided in the second case (L=16) for the set of numbers 0 through 65535 to be allocated to n_5 subsets M_1, \dots, M_{n_5} , and for a preset value d_i to be added to the generated decimal number if it is an element of the set M_i , it holding that $9999 < d_1 < d_2 < \dots < d_{n_5} < 34465$, and n_5 being a
20 natural number.

Another exemplary embodiment and/or exemplary method of the present invention provides for executing the following steps to generate the first digits of the PIN:

- 25 - a pseudo-random number composed of up to 36 hexadecimal digits is generated from the binary number (B) of length L;
- each hexadecimal digit of this number is converted using one different one out of the 36 possible mathematical mappings of hexadecimal digits into the digits 1 through 9, into a
30 digit of the digits 1 through 9;
- to even out the probability of the particular PIN digit occurring, the up to 36 decimal digits of the thus generated number are linked or associated in a mathematical operation

to form a decimal digit unequal to zero, which represents the first digit of the PIN;

and for the following steps to be executed for the second and each following digit of the PIN to be generated:

- a pseudo-random number composed of up to 210 hexadecimal digits is generated from the binary number (B) of length L;
- each hexadecimal digit of this number is converted into one decimal digit using each time one different one out of the 210 possible mathematical mappings of hexadecimal digits into decimal digits;
- to average out the probability of the particular PIN digit occurring, the up to 210 decimal digits of the thus generated number are linked in a mathematical operation to form a decimal digit, which represents the particular digit of the PIN;

[For this purpose] In another exemplary embodiment and/or exemplary method, [it may be provided that] the first digit of the PIN [is] may be generated [in] so that the up to 36 digits are linked using the group operation of any arbitrary mathematical group of the order 9, and that the second and the following digits of the PIN are generated, [in] so that the up to 210 digits are linked using the group operation of any arbitrary mathematical group of the order 10.

In this exemplary embodiment [of the] and/or exemplary method of the present invention, one hexadecimal number each is generated from N groups of 4 bit length each. It is intended at this point to convert it into a decimal digit. Altogether $(10 \text{ over } 6) = (10 \text{ over } 4) = 210$ different mappings of the hexadecimal digits into the set of decimal digits are available for this conversion. One possible mapping is forming the remainder in a division operation by 10: (0 -> 0, 1 -> 1, 2 -> 2, 3 -> 3, 4 -> 4, 5 -> 5, 6 -> 6, 7 -> 7, 8 -> 8, 9 -> 9, A -> 0, B -> 1, C -> 2, D -> 3, E -> 4, F -> 5). Following this mapping operation, the digits 0 to 5 occur with the rate

of occurrence of $1/8$, and the digits from 6 to 9 with the rate of occurrence of $1/16$. At this point, in order to obtain digits whose probability of occurrence does not deviate or deviates imperceptibly from $1/10$, it is proposed to convert the 210 hexadecimal digits, which were generated, for example, by applying the above-mentioned DES algorithm 14 times to the 64-digit binary initial number, (therefore, pseudo-random number, since the generated number is in no way randomly formed), using one each of the other 210 possible mappings, into a decimal digit and, subsequently, linking all 210 decimal digits to one single digit using a group operation of a mathematical group having ten elements. The probability of occurrence of each of the thus generated decimal digits is close to $1/10$.

[A next] Another exemplary embodiment and/or exemplary method of the present invention [provides] is directed to providing for the additive group of the integers modulo 10 to be used to link the up to 210 digits. In this context, 210 decimal digits are linked to form one single digit, in that one adds all digits and takes as a result, the remainder of a division of the sum by 10. The ten possible results that occur in the process constitute the elements of the additive group $Z_{10,+}$.

Another exemplary embodiment and/or exemplary method of the present invention provides for using the multiplicative group of the integers modulo 11 for linking the up to 210 digits. This group Z_{11}^* likewise has ten elements and is, therefore, suited for linking the numbers to a decimal digit. In Z_{11}^* , one calculates by multiplying two elements and dividing the result by 11. The remaining remainder forms the result of the operation. The zero is removed from the group. The 0 occurring in the digits indexes element no. 10 of the group Z_{11}^* .

Another exemplary embodiment and/or exemplary method of the present invention [provides] is directed to providing that the group of the symmetric mappings of a regular pentagon

(dihedral group) be used for linking the up to 210 digits, each of the ten symmetric mappings of this group being assigned a different decimal digit. To this end, it may also be provided for the digit 0 to be assigned to the identity mapping, digits 1 through 4 to be assigned the four rotations about the midpoint of the pentagon, digits 5 through 9 to be assigned to the five reflections about the five axes of symmetry of the pentagon. If one executes two symmetric mappings one after another, then a symmetric mapping again results. Based on these allocations, one can set up the following multiplication table:

*	0	1	2	3	4	5	6	7	8	9
0	0	1	2	3	4	5	6	7	8	9
1	1	2	3	4	0	6	7	8	9	5
2	2	3	4	0	1	7	8	9	5	6
3	3	4	0	1	2	8	9	5	6	7
4	4	0	1	2	3	9	5	6	7	8
5	5	9	8	7	6	0	4	3	2	1
6	6	5	9	8	7	1	0	4	3	2
7	7	6	5	9	8	2	1	0	4	3
8	8	7	6	5	9	3	2	1	0	4
9	9	8	7	6	5	4	3	2	1	0.

With the assistance of this table, the 210 digits are linked to one single digit in that, utilizing the result from the previous operation as a row indicator and utilizing the next digit as a column indicator, the next result in the table is read off successively until all digits are considered. The last result forms the desired digit of the PIN.

[Exemplary embodiments of the present invention are represented by several figures in the drawing and are elucidated in the following description. The figures show:

Figure 1]BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a diagram for generating a customer-specific binary code[;
]_

Figure 2[] shows a diagram for generating a PIN through
conversion to a decimal number[;].

Figure 3[] shows a diagram for generating a PIN by a digit-
by-digit conversion into decimal numbers[;
]..

Figure 4[] shows a diagram for generating a PIN by a digit-
by-digit conversion, including modulus formation[;
and
]..

Figure 5[] shows a diagram for generating a PIN by reducing
hexadecimal numbers with the assistance of
mathematical groups.[
Identical or corresponding parts are provided with the same
reference numerals in the figures.
]

DETAILED DESCRIPTION

Figure 1 depicts a flow diagram for converting personal data
Dc of a customer using a secret key K into a binary number B
of L bits length. The binary number B is part of the 64-bit
long encryption result, which was generated from the customer
data Dc using the DES algorithm.[
]

If the length of the binary number B equals 13, and if the
number of the PIN digits to be generated equals 4, then the
PIN, as shown in Figure 2, can be generated by interpreting
the binary number B as decimal number D by adding a constant C
thereto. The constant is to be selected such that the PIN does
not have any leading zeros. In this manner, 8192 different
PINS can be generated, which are absolutely uniformly
distributed over the number domain in question.

Figure 3 depicts how a binary number of length 13 can be converted into a PIN in that for each digit of the PIN to be generated, a number of bits of the binary number is converted into a decimal number, and a constant C is added to the resultant number D, to avoid having leading zeros of the PIN. In this manner, 7777 different PINS may be generated, which are absolutely uniformly distributed over the number domain in question.

Another [possibility]example for generating nearly equally distributed PINs from a binary number B is illustrated in Figure 4. The binary number B has 52 digit positions. To generate the four-digit PIN, the binary number B is subdivided into four subsets, which, in the example, have the same length. Each of these subsets is interpreted as a decimal number. The first digit of the PIN is derived as a remainder of a division of the first decimal number by 9. The following digits of the PIN are derived in each case as a remainder of a division of the following decimal number by 10. In this manner, 9000 different PINS may be generated, which are absolutely uniformly distributed.

From the personal data D_c of a customer, as shown in Figure 5, a sequence of 210 hexadecimal digits is generated with the assistance of a secret key and a random-number generator, in that, for example, an encryption result of the DES algorithm from Figure 1 is again encrypted using the algorithm, and so forth. The 14 64-digit binary codes resulting therefrom are converted into 14 hexadecimal numbers H_i , each having 16 digits. Lined up, this yields 224 hexadecimal digits, of which 210 enter into the generation of the PIN.

There are 210 different possibilities f_i for mapping the set of 16 hexadecimal digits into the set of the 10 decimal digits. Therefore, each of the 210 hexadecimal digits is converted using a different one of these mappings into a

decimal digit d_i . In order to produce a digit Z_i of a PIN from the 210 decimal digits, they are successively linked using the group operation F of any arbitrary ten-element mathematical group; the last result is the sought after digit. Thus, the previously non-uniform, statistical distribution of the 210 decimal digits is evened out. The entire process is repeated for each of the digit positions Z_2 through Z_4 of the PIN.

Analogously for the first digit of the PIN, 36 hexadecimal digits are generated, which are mapped with every other one of the 36 possible mappings of the hexadecimal digits into the set of the digits 1 through 9, into a digit between 1 and 9. The 36 decimal digits are linked to the first digit of the PIN using the group operation of any arbitrary mathematical group of the order 9. This enables 9000 different PINs to be generated which are nearly uniformly distributed. In generating 10^5 PINs, the maximum non-uniformities amounted to about 1.5 percent. This does not significantly raise the probability of a PIN being accidentally correctly guessed as compared to the theoretical minimum value. Thus, the method functions very reliably.

All mathematical groups having ten elements are fundamentally suited for use with this method. Known representatives include the additive group of the integers modulo 10, $Z_{10,+}$, the multiplicative group of the integers modulo 11, Z_{11}^* , as well as the group of the symmetric [mappings]mapping(s) of a regular pentagon D_5 , the so-called dihedral group. In the last instance, one decimal digit, which may be used for the calculation, is assigned to each of the individual elements of the group.

[

Abstract

]

ABSTRACT OF THE DISCLOSURE

[In a] A method for generating a personal identification number (PIN), made up of a number of N decimal digits, to be used for money cards and other devices requiring security, from a binary number having L digits, in particular from a binary code specific to an individual, the PINs are generated such that they are randomly uniformly distributed over the available number domain.